Misalignment Tolerant Three-Phase Wireless Fast Charging System for Electric Vehicles

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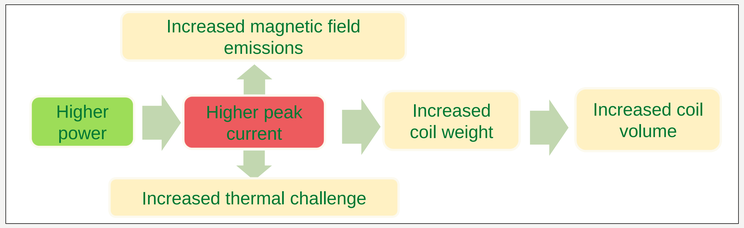
Overview

- There is a critical need for wireless EV charging systems in the range of 50 kW
- Single-phase wireless electric vehicle (EV) charging technology has the following challenges to scale for 50 kW [1].
  - Increased magnetic field emissions
  - Sub-optimal surface power density
  - Increased weight and volume
- ORNL polyphase wireless power transfer technology offers best-in-class power density and reduced emissions suitable for 50 kW wireless EV charging.

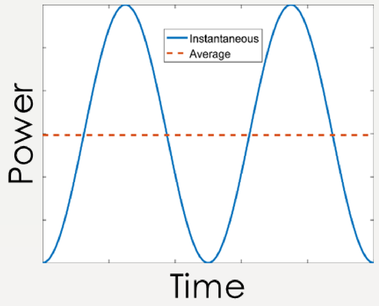
Objectives

- To develop and validate a vehicle integrated 50 kW polyphase wireless charging system to meet the design specifications of Stellantis vehicle platform.



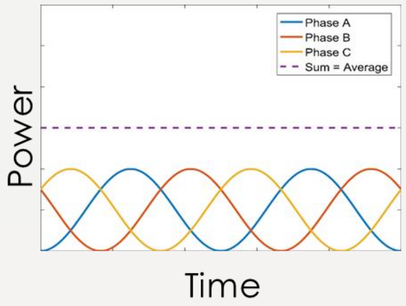
Challenges arising due relying on increasing primary transmitter current only to scale output power

Technology Innovation: Benefits of Polyphase wireless Charging System



Single-phase WPT Systems

- Single-phase systems "pulse" power across the airgap
- Low space-time average utilization since fields oscillate between peak values and zero
- Higher ripple currents



Polyphase WPT Systems

- Use rotating magnetic filed to transfer power
- Phase shifted coils and electrical excitation
- Much higher power density-improved space-time utilization
- Lower current ripple

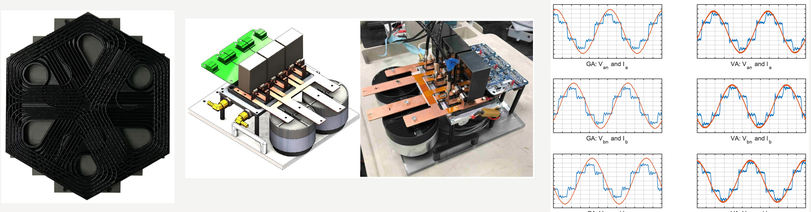
Challenge: SOA polyphase systems does not consider mutual inductance due to cross-coupling leading to suboptimal tuning.

Mitigation: ORNL tuning methodology accounts for and cancels out the spurious effects of cross-coupling.

Technical Accomplishments:

- This project is a new start
- Accomplishments prior to project inception: ORNL successfully completed 50 kW proof-of-concept demonstration [1]

Parameter	Demonstration Value
Power level	50 kW
Efficiency (dc-to-dc)	95 %
Magnetic airgap	150 mm
Specific power (receiver)	3.65 kW/kg
Power density (receiver0	195 kW/m^2



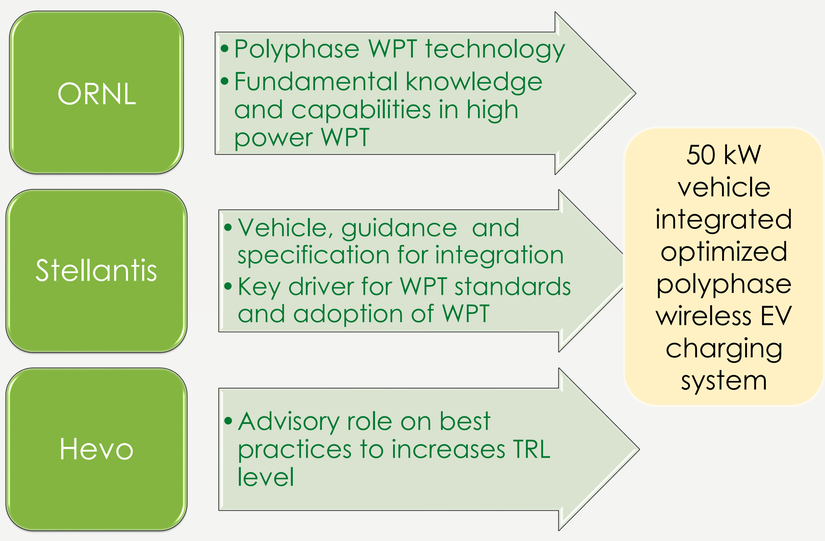
ORNL coupler prototype, power electronics inverter CAD model and prototype, and waveforms at 50 kW

Tasks and Timeline

Year 1				Year 2			
Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1 and 2 : Complete design of electromagnetic couplers and power electronics meeting Stellantis specifications for misalignment tolerance and power level		**Task 3 and 4**: Complete fabrication and benchtop characterization of polyphase couplers and power electronics.		**Task 4 and 5**: Complete laboratory testing of polyphase WPT system and power electronics integration with Stellantis vehicle.		**Task 5 and 6**: Complete implementation of control and communication and perform final vehicle integrated testing.	

Collaboration and Co-ordination

OAK RIDGE National Laboratory	• Project lead • Design, development, and laboratory validation of 50 kW polyphase wireless charging system including WPT couplers, resonant network, and power electronics
STELLANTIS	• Guidance and specification on vehicle integration and control and communication for battery management system • Support with final vehicle integrated validation
HEVO	• Tier-1 partner with intent of producing wireless EV charging systems at scale • Advise on best practices for achieving higher TRL level at hardware and system level



Reference

[1] J. Pries, V. P. N. Galigekere, O. C. Onar and G. Su, "A 50-kW Three-Phase Wireless Power Transfer System Using Bipolar Windings and Series Resonant Networks for Rotating Magnetic Fields," in IEEE Transactions on Power Electronics, vol. 35, no. 5, pp. 4500-4517, May 2020, doi: 10.1109/TPEL.2019.2942065.